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REGIONAL COOPERATION

Europe-Africa permanent link through the Strait of Gibraltar

Note by the Secretary-General

1. The Secretary-General has the honour to transmit to the Economic and Social Council the evaluation report prepared by the Executive Secretaries of the Economic Commission for Africa and the Economic Commission for Europe on the Europe-Africa permanent link through the Strait of Gibraltar.

2. In its resolution 1991/74 of 26 July 1991, the Economic and Social Council, inter alia, requested the Executive Secretaries of the Economic Commission for Africa and the Economic Commission for Europe to prepare an evaluation report on the studies relating to the project in the period 1982-1993 for submission to it at its regular session of 1993.

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Annex

EVALUATION REPORT ON THE STUDIES CARRIED OUT BETWEEN 1982 AND 1992 ON THE PROJECT FOR A EUROPE-AFRICA PERMANENT LINK THROUGH THE STRAIT OF GIBRALTAR

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I. INTRODUCTION

1. The possibility of linking Europe to Africa by means of a fixed crossing of the Strait of Gibraltar has been the subject of many studies for over a century. The Governments of Morocco and Spain gave major impetus to these studies by deciding under a specific agreement on bilateral cooperation adopted on 24 October 1980 to undertake joint scientific and technical studies on the fixed crossing project. In accordance with that agreement, later supplemented by an additional agreement adopted on 27 September 1989, the studies are being carried out by an intergovernmental Joint Committee with the assistance of two State companies, the Moroccan Société Nationale d'études du détroit (SNED) and the Spanish Sociedad de Estudios para la Comunicación Fija a través del Estrecho de Gibraltar (SECEG).

2. The impetus given to the studies on the project for a permanent link through the Strait of Gibraltar by the decision taken in 1980 by the Spanish and Moroccan Governments to carry out the studies jointly, the geostrategic importance of such a project and the major role it could play in the development and the integration into the international economy of many countries and regions formed the basis of the Economic and Social Council's interest in the progress of the studies. This interest was shown in a number of resolutions requesting the Executive Secretaries of the Economic Commission for Africa (ECA) and the Economic Commission for Europe (ECE) to prepare follow-up and evaluation reports on the studies.

3. In its resolution 1991/74 of 26 July 1991, the Economic and Social Council requested the Executive Secretaries of ECA and ECE to prepare an evaluation report on the studies relating to the project in the period 1982-1993 for submission to it at its regular session of July 1993. This report therefore responds to that request by the Economic and Social Council.

4. The studies that are the subject of this evaluation are all studies and analyses which were carried out between 1982 and 1992 under the auspices of the Spanish-Moroccan intergovernmental Joint Committee since 1980, either directly by the two companies, SNED and SECEG, or by scientific bodies of the two countries or national or international consultancy or prospecting firms with which those companies made agreements or service contracts. These numerous and diverse studies, a detailed list of which is provided in the annex to this report, concern the various aspects to be considered at the initial phase of research on a large-scale international infrastructure project. These aspects range from the characteristics of the rocks that would support the structure to the international legal aspects involved, and include the various options for the structure, traffic estimates and economic aspects.

5. The studies are currently at a "feasibility 2 phase" which covers the period 1991-1993 and has the objective of supplementing the knowledge previously acquired and preparing a feasibility study of the project. This phase is currently being carried out in accordance with a general programme of work consisting of five specific programmes, namely, physical environment, engineering, socio-economic environment, evaluation and external relations. This programme of work has also been evaluated in view of the importance of such

an evaluation for carrying out the ongoing studies and of the input it can provide for this report.

II. METHOD OF WORK

6. In order to carry out the evaluation work, the ECA and ECE secretariats decided, in close cooperation with the Moroccan company SNED and the Spanish company SECEG, to divide the studies carried out during the evaluation period into six main areas, namely, geological studies, tunnel studies, bridge studies, studies on traffic estimates, economic studies and legal studies, and to entrust the evaluation of each of these areas to a highly qualified international expert.

7. The sectoral evaluations carried out by the experts were concerned with the methodology used in the studies, the results obtained and the programme of work for the current phase of studies, and produced conclusions and recommendations for future work. Initially the Commissions, the companies and the experts themselves had in-depth discussions of the sectoral evaluation reports submitted by the experts. These discussions were undertaken vertically, with each expert, and horizontally, with all the experts, so as to take into account intersectoral aspects. These discussions and the observations deriving from them served as a basis for the experts in drawing up their final reports. The sections that follow are summaries of those reports.

8. The technical cooperation of the companies consisted essentially in assisting the Commissions and consultants in respect of (a) access to the studies to be evaluated and provision of the documents selected, (b) obtainment of additional information of interest for the evaluations, (c) organization of site visits, and (d) participation in follow-up. The companies and the Commissions coordinated their work at five meetings held at Addis Ababa, on 5 and 6 March 1982; Geneva, on 7 and 8 May 1992; Madrid, on 10 and 11 December 1992; Rabat, on 15 and 16 February 1993; and Geneva, on 25 and 26 March 1993.

9. Although this report is based primarily on the evaluations of the experts and reflects their views, conclusions and recommendations, it represents the result of cooperation between the Commissions, the research companies and the experts. It is important to note that the Commissions received no additional funding to undertake this report; the report would therefore not have been possible without the significant financial support of SNED and SECEG, which financed most of the activities that led to its preparation and also met the cost of recruiting the experts and paid for them and members of the two Commission secretariats to attend the various meetings organized to ensure the effective coordination and quality control of the work.

III. EVALUATION OF STUDIES

A. Geological studies

10. Given the magnitude of the project to construct a permanent link through the Strait of Gibraltar, information on the geological characteristics of the specific area that the project involves, and of the overall region, is a prerequisite for a feasibility study of the project. The studies which were conducted - under the generic heading of geological studies - in order to obtain such information dealt with geological aspects per se (characteristics and structure of rock), geophysical aspects (movements, magnetism, bathometry and meteorology) and geotechnical aspects (strength and permeability of rocks) of the area. The evaluation of these studies dealt with particular aspects relating to the tunnel option, where geology plays an essential role throughout the crossing. Many considerations, particularly regarding seismicity and characteristics of rocks, will also apply in respect of the bridge option, where geological data are especially important as regards the stability of anchor points and the construction of piers. However, physical characteristics relevant to the bridge option alone (wind and currents) will be analysed below in the section on that particular topic.

1. Evaluation of methodology

11. The geological studies conducted between 1982 and 1992 naturally took into account the abundant existing literature on the geology of the Gibraltar arc as well as long-standing theoretical data and general geodynamic concepts concerning the geological evolution and formation of the region. However, the studies also took into account detailed geological research conducted between 1960 and 1980 on both sides of the Strait by the same scientific team. That research led, among other things, to fundamental changes in the previous geodynamic understanding of the area. Beginning in 1980, members of the team were invited by geologists in charge of the various studies to take part in a great number of joint visits to the site and to participate in in-depth discussions. The outstanding cooperation that developed between the two groups of experts was considered extremely useful to the studies.

12. The studies were based on numerous drillings, tests and surface studies conducted on dry land. New detailed geological surveys were conducted on both sides using the close-mesh technique and highly technical means and modern methods, such as the study of microflora for precise dating of stratigraphic sequences. Seven mechanical drillings at hectometric depths were conducted on the north side and 16 on the south side and, overall, successfully achieved their intended goals (tectonic or stratigraphic superpositions, permeability and stability of rocks). In addition, the residue from four pluri-kilometric borings, drilled between 1955 and 1970, was re-examined in detail and subjected to a modern micropalaeontological study.

13. In order to analyse submerged areas, certainly the most difficult aspect of these studies, several methods were used: geophysical surveys using seismic reflection, sampling from the seabed (approximately 900), bathometric surveys using side-scan sonar and offshore drilling.

14. In order to analyse natural seismicity, in addition to inventories of modern seismic occurrences, a study of the mechanisms at the centre of recent tremors in the Gibraltar arc, and the recording of microseismic measurements, recently begun, have been found to be very useful.

2. Evaluation of results

15. The studies have revealed that the land areas were formed by a piling-up of kilometre-thick highly tectonized overthrust nappes, made up primarily of flysch material of the Cretaceous and Palaeogenic periods, indicating between 130 million and 20 million years of age. The geological maps prepared during the studies were found to be accurate and most adequate. The studies also demonstrated the impermeability or the very low permeability of these flysch units and presented convincing evidence that while on the surface, particularly on the south side, the rock mass is distributed in a rather irregular fashion, at a greater depth it is in fact well organized and will probably prove to be strong enough at the time of perforation.

16. The studies furthermore confirmed the similarity of the type of rock sequences and their tectonic structure on each side of the Strait. Even though the geological characteristics of the submerged areas are not known in detail, the experts have concluded that, contrary to what geodynamics specialists had long thought, there was no precise delineation running beneath the waters of the Strait, separating the Eurasian and African plates, at least as of the end of the lower Miocene (15 million years) but instead a rather large zone that goes from the Iberian Meseta to the African substratum. This information is of fundamental importance for the project since it means that the structure would remain in the same formation throughout the crossing. In any case, studies of seismicity have shown that even if the area of the Strait is surrounded by active zones and if, naturally, distant earthquakes can affect it - superficially - as they do other regions, there is no epicentre in the area of the Strait. Recorded measurements of microseismicity appear to have confirmed this low activity.

17. The use of sonar in the submerged areas has made it possible to produce remarkable bathometric maps which have led to the identification of two possible paths for the permanent link: (a) the so-called "Sill route", or the shallowest route, situated between Punta Paloma in Spain and Ras Malabata in Morocco, approximately 28 km from coast to coast and with a maximum waterdepth of 300 m; and (b) the so-called "Strait route", or the shortest route, situated between Punta Canales in Spain and Ras Cires in Morocco, approximately 14 km from coast to coast, but with waterdepths in excess of 800 m in places, even though the depth at the very centre of that section is 450 m.

18. With regard to the characteristics and structure of the rocks in the submerged areas, while sampling by means of dredging has provided only a few indications of palaeontological facies and datings, and while artificial seismic movements were not of any real assistance in identifying the hard strata whose presence they revealed, offshore drilling did make it possible to ascertain the presence of flysch units in the submerged areas, which in turn confirmed that the outcropping geological formations on both sides were continuous. However, these results have not yet made it possible to produce a reliable geological

cross-section of the submerged areas. Even if one can reasonably hope that the flysch units have geotechnical characteristics at least equal to those of the mainland flysch units, for a project of this magnitude, particularly when contemplating the tunnel solution, extensive precautions should be taken and the relevant information should be expanded to the extent possible.

3. Conclusions and recommendations for future studies

19. The geological studies analysed in a serious and almost exhaustive manner those aspects that are essential to understanding the geological characteristics of the area of the Strait and used high-quality methods and concepts. As these studies concluded, it can be stated with a reasonable degree of confidence that there is no major geological obstacle to the construction of a permanent link, tunnel or bridge across the Strait of Gibraltar and that, as far as the tunnel option is concerned, boring could be performed in various flysch units which are relatively easy to drill through and have low to zero permeability.

20. However, while the geological characteristics of the land areas are well defined, those of the submerged areas, which are essential for the tunnel option, are certainly not known in any detail. Even if the flysch units all belong to the same large family and the terrains, which are impermeable and strengthened by rhythmic alternations, must be fairly easy to drill irrespective of their tectonic structure, in a project of this scale one must take every possible precaution and aim to acquire as precise a knowledge of the submerged areas as possible.

21. The actual work programme involves a series of research projects on almost all the geological aspects evaluated. However, in the light of the results obtained hitherto and those yet to be obtained, it is recommended that priority be given to prospecting which is directly geared to securing information about the submerged areas and to the engineering requirements of the permanent link, more specifically (a) to the geotechnical experimentation carried out on the two sides (the shaft at Bolonia, the experimental gallery at Tarifa, and the shaft and galleries at Malabata), (b) to carrying out a new side-scan sonar survey of the deep sections of the Sill route, and (c) to offshore drilling operations.

22. As far as future studies are concerned, gaining information about the geological characteristics of the submerged areas will still be the main objective, especially for the tunnel option, and will still be far from complete even at the end of the present phase. In view of their limited spatial extrapolatability, drilling operations can provide only a limited knowledge of the submerged areas. However, the importance of a detailed geological cross-section should not be exaggerated, since the flysch units all belong to a single family and must be fairly easy to drill irrespective of their tectonic structure. If one wanted to take maximum precautions, the ideal method would be to construct a reconnaissance gallery along the course decided on for the tunnel itself. Without such a gallery, offshore drilling operations will have to be pursued. In the case of the Ras Cires-Ras Malabata bridge, the nature of the rock at the point where the sea depth is 450 m, where the central pier would be situated, will, of course, have to be determined.

B. Tunnel studies

23. The problem of the technical feasibility of a tunnel below the Strait of Gibraltar has been dealt with during the period 1982-1992 in 23 specific reports and discussed at five specialist conferences, with the results published in proceedings. The topics covered included geology, geomorphology, topography, oceanography, seismology, geotechnical conditions and properties of the relevant ground strata, design concepts of the tunnel, selection of tunnelling systems and methods, lining systems, the influence of traffic and transportation aspect of tunnel design and cost estimates.

1. Evaluation of methodology

24. While the methodology used in the studies varies from source to source, the coverage of topics and the database are definitely wide enough to provide an adequate basis for a feasibility study of the Gibraltar Strait tunnel. In general, the design and the construction of a tunnel are dominated by the geological, hydrogeological and geotechnical conditions and by the selection of an appropriate tunnelling method to cope with these conditions. The evolution of the studies related to the Gibraltar tunnel shows that these factors have been considered and gradually integrated into a framework which is consistent enough to allow an evaluation of the feasibility of the tunnelling solution.

25. The geological model of the area is well known and documented (see paras. 10-22). The evaluation of geological studies has concluded that, although boring a tunnel through the subaqueous rocks should not face major geological problems, the knowledge of those rocks has to be significantly improved. However, in view of the extraordinary difficulties with drilling in the deepest sea areas, the detailed knowledge of stratigraphy may never be achieved before the excavation of the tunnel. In this case, selecting a tunnelling system capable of dealing with all the anticipated ground types should represent an acceptable solution. In fact, for the feasibility of a project with the magnitude and importance of the Gibraltar tunnel, the application of such a system is essential. Some of the more recent studies reflect the latest technological developments in automated and fully mechanized tunnelling systems.

2. Evaluation of results

26. From the evaluation of the results of the studies, it appears that the tunnel alignment would encounter, for its entire length, flysch formations, the geotechnical properties of which have been studied in sufficient detail to provide an input into the analyses of the expected behaviour of the excavated tunnel and of the loading on the tunnel lining.

27. The horizontal alignment of the tunnel is proposed to follow the "Sill route" (Ras Malabata-Punta Paloma). This choice is most appropriate since it allows the vertical alignment to be placed at a minimum possible depth, which results in the shortest overall length of the tunnel. However, even with this alignment, the maximum sea depth would be some 300 metres, which would make the Gibraltar crossing the deepest undersea tunnel so far. Nevertheless, analyses

of the ground response and of loading on the tunnel lining have shown that even at this depth tunnelling would be manageable within the limits of current technology. Considering the length of the tunnel and the geological conditions expected the most suitable and economical tunnelling system would be a fully mechanized tunnel boring machine with a precast segmented lining.

28. The tunnel solution currently retained, similar to the one implemented in the Channel tunnel, consists of two single-track rail tunnels and a service tunnel. Total length would be 38.6 km, out of which 27.7 km under the sea. Tunnels would be excavated 100 m under the seabed. Traffic will consist of ordinary trains and road vehicle shuttle trains. At a first stage, only one rail tunnel and the service tunnel would be built. Several cost estimates have been included in the studies, showing a remarkable consistency in their results. The cost of the entire scheme was estimated to be around US$ 6 billion. This cost, which includes track and signalling equipment as well as shuttle trains, can be significantly reduced by initially developing as foreseen one or two tunnels only, by shortening the overall length of the tunnel through reduction of the tunnel overburden and by increasing the rate of progress of the tunnelling machines.

29. The above findings have been systematically verified by data from similar large undersea tunnels such as the Seikan tunnel in Japan, the Channel tunnel between France and the United Kingdom, the Storebelt tunnel in Denmark and several other tunnels of comparable length. In this respect, special attention has been given to the credibility of results reported in paragraphs 27 and 28 above.

3. Conclusions and recommendations for future work

30. The studies carried out so far on various aspects of the tunnel have satisfactorily demonstrated that the tunnel solution is entirely feasible. While a number of questions related to the tunnel require an answer, ways and means exist within the present state-of-the-art of tunnelling to obtain such answers with sufficient reliability. Further progress on this project thus depends on the availability of resources rather than on any major breakthroughs in tunnelling technology. This conclusion can be fully supported by experience from similar large undersea tunnels and by application of the most modern technology as it exists world wide today. However, to be sure the knowledge of the subaqueous rocks will have to be significantly improved.

31. After 10 years of extensive and productive studies (1982-1992), the project has reached a stage when any further progress requires a shift from "desk" type studies prevailing so far to field activities. These field activities should include additional drilling (both at land and at sea), further testing of rocks and, above all, the excavation and observations carried out on an experimental tunnel. Therefore, the experimental tunnel at Tarifa, proposed for the current phase of the project, is considered not only a further step in the right direction but also an absolutely necessary prerequisite for any further progress. For this purpose, detailed recommendations concerning instrumentation and monitoring are provided in the sectoral evaluation report. The experimental shaft and radial galleries foreseen in the Moroccan side are also considered important.

32. With regard to future work, in addition to the experimental tunnel, which represents by far the most important step forward at this time, the project should require in particular deep boring of the seabed. However, in view of the difficulties with drilling in the deepest sea areas, and the limited knowledge drilling will provide, a reconnaissance tunnel will be the ideal method. Otherwise, it is suggested that, after a number of pilot boreholes, the actual drilling programme should not start until experience with tunnelling through different ground types is obtained from work on the experimental tunnel. Another field which would deserve some consideration at this stage is the elaboration of contractual strategies with a view to an appropriate risk sharing.

C. Bridge studies

33. During the period from 1982 to 1992 the technical feasibility of a bridge across the Strait of Gibraltar has been the object of thorough studies. The bridge studies have to a very large extent been directed towards investigating the most appropriate structural solutions to meet the special conditions, particularly extreme water depths over a width of more than 10 km, in the Strait of Gibraltar.

1. Evaluation of methodology

34. The methodology applied in the bridge studies is estimated to be in full accordance with the procedures that are generally used in the initial phase of investigating bridge solutions. In the first phase, the studies were characterized by an interaction between establishing the design basis and preparing the early conceptual designs. The basis for the design has been set up partly by extracting relevant rules from existing specifications and partly by measurements and analyses of the special conditions in the actual location. It is a general observation that such basis has been carefully selected (and probably slightly conservative) so that the assumptions governing the structural analyses should not lead to an overoptimistic evaluation.

35. In addition to the basic geological conditions (see paras. 10-22), data and analyses which were taken into account as a basis for the design include, inter alia, seismicity, wind and currents. Seismicity was taken into account by assuming a peak ground acceleration of 0.27 g derived from the records of the 1755 Lisbonne earthquake although according to more recent analyses such a figure would be very conservative. Wind speeds used as a basis for design (52 m/sec at the girder level and 59 m/sec at the pylon top) are also somewhat conservative estimates although, if more detailed wind measurements confirmed the estimates as realistic, then the minimum critical wind speed would have to be increased (from 65 m/sec to some 70 m/sec). Currents, strong and complicated in the Strait as they usually occur in two-layer flows, were taken into account by assuming a rather forceful east-west current (2.5 m/sec) in the upper 100 m.

36. In the following phases of the studies, a number of conceptual designs were prepared with the emphasis laid on investigating the most critical features of this particular bridge scheme, such as construction of bridge piers on waterdepths over 250 m, i.e. more than three times larger than ever built for a

bridge before, structural system for bridges with extreme spans and their aerodynamic stability. With regard to pier construction on deep waters, the studies have taken into account the existing technology and the pier designs are, to a large extent, based on experiences from already built offshore platforms in the Mexican Gulf, the North Sea and others as these have already been built at waterdepths exceeding those of the Gibraltar Strait. For the bridge superstructures, the emphasis was laid on investigating the applicability of suspension bridges since all existing bridges with spans of more than 600 m are built as suspension bridges. These investigations mainly comprised analyses by existing computer programmes and wind tunnel testing.

2. Evaluation of results and comparative analysis with similar projects

37. The conceptual bridge solution proposed in the studies is a multispan suspension bridge with the main cables supported by triangular pylons on gravity base concrete piers, which is considered to be the most technically feasible solution with the present knowledge of the soil conditions. Such a bridge could actually be built today by combining structures that have already been completed or are under construction. Thus, the bridge over the deepwater channel could be composed of a series of three-span bridges corresponding to the Akashi Kaikyo bridge, which is under construction with 1,990 m spans, and the corresponding bridge piers could be constructed as the Troll gravity base offshore platform or the Bullwinkel steel jacket platform. It is, however, evident that such bridge would not be optimal, and in the studies more promising solutions are investigated. Several of these will require only a modest extrapolation of the present technology so they must be evaluated as realistic.

38. Two main bridge alignments have been retained in the studies. The one which has been most intensively studied is the 28 km long alignment between Ras Malabata in Morocco and Punta Paloma in Spain ("Bridge 28"), which presents the lowest waterdepth. The choice is considered appropriate. For the main bridge, the studies present three alternative solutions with three different spans: 2,000 m, 3,000 m and 3,500 m respectively. The solution preferred in the studies consists of a 14 km long main bridge and two 8 km and 6 km long access offshore viaducts. The main bridge is a multispan suspension bridge composed of three main 3,500 km spans and two side 1,750 m spans. Triangular pylons are supported by gravity base concrete piers founded at a waterdepth of some 300 m. Anchors, which are gravity base concrete blocks, are founded at a waterdepth of some 60 m. The 30 m large girder is in principle of the monobox type. The solution, as described, is designed for 2 x 2 lanes road traffic. Construction costs are estimated at ECU 8 billion (1992).

39. The feasibility of constructing 3,500 m spans will obviously require further investigations but nothing indicates that such spans are not feasible. With regard to the proposed girder, it is now generally recognized that the single box proposed might be inadequate for the very long spans, e.g. exceeding 2,000 m. Based on a number of preliminary wind tunnel tests, the twin box concept appears to be the most promising.

40. In the studies, construction of the bridge at the location where the distance between the two coasts is shortest, i.e. the alignment between

Punta Canales in Spain and Ras Cires in Morocco ("Bridge 14"), has also been considered. This alternative is evaluated as a particularly interesting solution although much more ambitious. Here the total bridge length will be approximately 14.5 km but the waterdepths are much larger. It has been shown that with a four-span bridge with two main spans of 5,000 m length and two side spans of 2,000 m, the waterdepth at the pier locations can be limited to 450 m. These are very extreme conditions indeed, but it cannot immediately be ruled out that it would be technically feasible to overcome even this obstacle. In addition, to cross the Strait at the shortest possible way, such a bridge would be very appropriately placed with regard to the present Strait corridor and would provide ideal navigation conditions.

41. For the bridge in the Punta Paloma-Ras Malabata, thorough cost estimates have been worked out based mainly on unit prices from recent tenders on comparable jobs. However, in a number of aspects the conditions at the Strait of Gibraltar are more extreme than encountered elsewhere so some uncertainty does remain. At the present level of the investigations it can be concluded that the probable cost of a motorway bridge across the Gibraltar Strait will be between US$ 7 and 9 billion, and that a single railway track will increase the cost by approximately US$ 1.5 billion.

3. Conclusions and recommendations for future studies

42. The bridge studies are generally evaluated as relevant and they have certainly addressed the major issues of designing a bridge across the Strait of Gibraltar. Although they only cover a small fraction of the design work that would be required before the actual construction could start, the results indicate that it would be technically feasible, although very demanding, to build a bridge across the Gibraltar Strait.

43. In the present programme of work, emphasis has been placed on the 28-km Ras Malabata-Punta Paloma bridge. However, the present review has shown that there are many unexplored potentials in the Ras Cires-Punta Canales bridge or "Bridge 14". Therefore, in addition to continuing the investigations of the most crucial parts of the project, it is recommended that designs for both bridges be prepared to the same level and that studies of the full span range from 2,000 m to 5,000 m be furthered.

44. For future studies, it is highly recommendable to specify the overall acceptance criterion before detailing any further the main structural elements of the bridge. This will form the basis for determining the size of the design ships to be used during the analysis of pier strengths. Also, the acceptance criterion will allow a determination of the seismic actions to be considered during design.

45. Although the result of the studies must be evaluated as technically feasible, it still appears to be favourable to further study the basic concepts of the design of deepwater bridge piers, of the bridge girder, of the cable system and of the pylons as it appears that there is still scope for arriving at even more favourable solutions than those of the existing studies. In particular, the reinforcement and protection of piers against ship collision, the aerodynamic stability of the girders including wind tunnel tests and the

full adaptation of the technology of pier construction for offshore platforms to the specific requirements of a bridge should be studied in the future. Another aspect to be considered is the introduction of a rail line in addition to the 2 x 2 lane. As indicated above, all designs should be prepared for both alternative bridge solutions and the range of spans to be studied should be enlarged from 2,000 m to 5,000 m.

D. Studies on traffic estimates

46. The evaluation essentially involved traffic studies carried out in line with the basic study published in February 1992 and entitled "Economic feasibility study of the Europe-Africa permanent link through the Strait of Gibraltar".

1. Evaluation of methodology

47. The permanent link project has developed a proper database which is continually updated and covers 11 countries of Western Europe and 22 African countries, and constitutes an important tool for socio-economic knowledge of the region. This database has been considered reliable compared with other existing databases. However, the size of the region concerned and the large number of parameters which are taken into account mean that there have to be improvements both in time-specific studies for passenger traffic and in determining the different modes of transport used for goods traffic, and in the descriptive level of the proposed estimate scenarios.

48. As for the forecasting model, which is analogous to that used for the Channel Tunnel project, the methods for calculating journey time and transport costs for each mode of transport and each journey, the modal split model between pedestrians and vehicle passengers, the modal split models for goods traffic and the concepts employed for estimating the impact of the permanent link on tourist movements are considered valid and appropriate, and as accurately reflecting the trading status of the area concerned, and its probable development. However, in the future it will be necessary, among other things, to introduce the possibility of temporal adjustment of the traveller forecasting models and to secure a better breakdown between air transport and maritime transport without vehicle.

2. Evaluation of results and comparative analysis with similar projects

49. The results produced by the study on traffic estimates are summarized in the table below.

Table

Summary of traffic estimates

(In millions of units)

Category of traffic	2000				2025			
	Trend		Sustained		Trend		Sustained	
	Bridge	Tunnel	Bridge	Tunnel	Bridge	Tunnel	Bridge	Tunnel
Passengers	8.7	8.8	10.3	10.5	16.0	16.6	23.3	24.8
Diverted	5.9	6.3	7.0	7.5	10.8	11.6	16.4	17.7
Engendered	1.6	1.9	1.9	2.4	2.9	3.6	4.6	5.7
Created	1.2	0.6	1.4	0.7	2.3	1.4	2.3	1.4
Goods	2.6	2.9	4.2	4.5	10.2	10.1	33.0	31.9
Diverted	2.2	2.5	3.5	3.9	7.5	7.9	26.8	26.7
Engendered	0.3	0.3	0.6	0.5	1.3	1.1	5.0	4.1
Created	0.1	0.1	0.1	0.1	1.3	1.1	1.2	1.1

NB. Diverted: from maritime or air transport to the permanent link.

Engendered: by the general improvement in transport conditions.

Created: by the local structuring effect of the permanent link.

50. Evaluation of these results has demonstrated their overall validity: the coherence between the different hypotheses, the probability of the total traffic figures, and annual average growth rates, even if the difference between the two scenarios may be considered too great and the growth rates somewhat optimistic. Detailed analysis of the table shows, among other things, that the flows are in practical terms independent of the nature of the link, whether bridge or tunnel, and the traffic created would be significantly higher if the permanent link were of the bridge type.

51. Compared with the traffic estimated for the Channel Tunnel, the traffic estimated for the permanent link through the Strait of Gibraltar is significantly less. However, the passenger traffic is of the same order of magnitude as that anticipated for Scanlink. With regard to goods traffic, the growth rates for the permanent link are considered optimistic by comparison with those for Eurotunnel or Scanlink.

3. Conclusions and recommendations for future studies

52. The traffic estimates show results which are considered modest but reliable and reasonable, even if adjustments and improvements will have to be made in future both to the database and to the scenarios and models.

53. The work programme is considered to be positive in terms of traffic estimates, since it envisages the creation of a database for continuous or periodic updating, as well as the computerization of the forecasting system, which is entirely in line with the recommendations set out below. However, a continuous passenger survey must be introduced. The study of the regional impact of the permanent link, which is envisaged in the programme, is regarded as another positive element. For future studies, it is recommended that progress be made in two directions in particular: (a) the creation of a large, historical and periodically updated database, organized as far as passengers are concerned on the basis of systematic surveys undertaken at the frontiers and as far as goods are concerned on the basis of customs information obtained directly from each country, and (b) the complete computerization of the forecasting system as a precondition for the adjustments and improvements proposed in the sectoral evaluation report.

E. Economic studies

54. The study of the Strait of Gibraltar's fixed link has considered the potential economic, financial and social implications of the development of the project. The core of this analysis is to be found in the study on the economic feasibility of the project published in February 1992. The evaluation incorporates results from other studies in particular those related to the economic impact of the construction project on the local zone and those related to tourism. The following considerations are therefore mainly dealing with the above-mentioned study.

1. Evaluation of the methodology

55. The analysis of the economic, financial and social aspects of the Gibraltar project has been conducted by the authors of the study following closely the experience gained in the Channel Tunnel project. In accordance with such experience, the following methodology has been applied:

(a) Growth scenarios have been established in order to compute the potential demand for transport of goods and passengers along the West Mediterranean corridor and a modal split model (see paras. 46-53) has been used to allocate this demand to the competing transport systems, including the new fixed link;

(b) From the result of this allocation it is immediately possible to compute the welfare gains (or losses) of the users of the fixed link (passengers, transport enterprises), of Governments (taxes) and of the link operator (net revenue from tolls less costs); the welfare gains of the users is made up of monetary gains (due to reductions of transportation costs) and of gains in time (transformed into monetary values);

(c) The financial accounts for the link operator are established using traffic estimates and hypothetical fare structures, as well as distribution in time of investment costs, of their financing, and of maintenance costs. The economic accounts include the financial accounts of the link operator as well as the welfare gains and losses of the other economic agents;

(d) As it is expected that a large structuring infrastructure will generate additional economic and social development in the surrounding area, impact analysis models (input-output open Leontief type) have been used to estimate them.

56. Overall this methodology follows a logical sequence and has been tested satisfactorily in other large projects of transport infrastructure.

57. Evaluation of the initial traffic database used in the models has many problems (see paras. 46-53), but an effort has been made to keep transparency and consistency, with the end result that the margins of error induced by the low quality of some statistical estimates can be reasonably assessed.

58. The estimation of the models has also shown that, while computation of financial accounts follows well-established procedures, the notion of welfare gains, derived from the estimate of the value of time gains by the users, raises more difficulties for very long distance traffic as encountered in the Gibraltar link. Several improvements are possible in this respect.

59. The less convincing aspect of the methodology refers, however, to the computation of the social welfare gains possibly induced by the link (new development investments in the area, new indirect employment and incomes), that have been contemplated with a highly static approach, due to the initial obvious difficulties of building a dynamic model of the area of influence (in particular the local surrounding area).

2. Evaluation of results

60. The existing results, although they are preliminary, can already provide some interesting and rather solid economic, financial and social conclusions. Should the link start operating in the year 2005, by the year 2020, in a reasonable trend scenario, the total annual traffic should be of the order of 15 million passengers and 8.5 million tons, without practical differences between a tunnel or a bridge.

61. Under these demand conditions, and assuming a fare structure consistent with the market estimates, as well as a capital investment cost of ECU 6.5 billion (1989) the project would require a public subsidy of 33 per cent, in order to provide a financial return of investment (ROI) in real terms of 9.5 per cent.

62. Always under the same conditions and using the wider context of benefits and costs with welfare gains and losses, the project would show an economic ROI of 11 per cent, i.e. slightly below other large infrastructure projects in Spain and in Morocco, but in any case acceptable for a project with wider geostrategic justifications.

63. A particularly interesting result is that a substantial share (about 40 per cent) of the welfare gains of the users is expected to take place in areas outside the bilateral relation between Spain and Morocco and therefore justifies the need of a multilateral project, including contributions from other countries and areas to the necessary partial subsidy of the investment costs; in the present institutional context the link brings welfare gains to Morocco/Spain, European Community (EC)/Arab Maghreb Union (UMA) and Africa/Europe relations.

64. The link is expected to create indirectly some 30,000 to 35,000 jobs and could bring up to 1.4 million tourists in the year 2020 to Morocco. These development effects are a minimum estimate and could be substantially increased, should appropriate policies be adopted to stimulate new investments in northern Morocco and southern Spain. The end result of these development policies could also be important for the development of new traffic and for the financial and economic results of the project.

3. Conclusions and recommendations for future studies

65. The economic studies made so far do not provide arguments for the decision between a tunnel or a bridge (the final investment cost estimates for the alternatives will therefore play an essential role in this decision, and for the moment these estimates are so uncertain that the economic studies have been made on the basis of a single investment value for a standard link of undefined characteristics), but they clearly show that the project has already a reasonable economic basis.

66. As a long distance transport infrastructure both for passengers and freight, the Gibraltar link could bring substantial gains to users by reducing the time and cost of many relations; for the moment, long distance transport between Europe and Africa is growing very slowly, and the economic studies made

assume a continuation of these trends (trend scenario); even in this case the project is broadly acceptable. Should a more desirable environment develop in the future of enhanced cooperation between these two areas of the world, and in particular between EC and UMA, the link would be not only justified, it would be an indispensable element of a transit system of increased capacity and efficiency.

67. Furthermore an international transit infrastructure would be better justified at this point if it could also be an element of a more intensive economic relation between the two areas of the impact zone (northern Morocco and southern Spain), that constitute a key strategic frontier region. In this context, it seems appropriate to include the link in a wider development programme of the region.

68. While detailed recommendations are included in the sectoral evaluation report, the following can summarize them in broader terms: (a) the computation of welfare gains and losses should be improved as a result of some changes in the transport demand models, in the model split and in the computation of the value of time; (b) a detailed financial simulation model should be developed in order to test different financial engineering proposals and institutional configurations; (c) the computation of possible development impacts of the project requires more comprehensive studies and possibly the development of a dynamic simulation model of the impact zone; furthermore a detailed analysis should be made of other infrastructural requirements in order to fully stimulate the development potential of the project; and (d) from the present level of feasibility study, the project should move to a more detailed financial, economic and social evaluation of the existing alternatives.

F. Legal studies

69. During the period 1982-1992, legal studies on the proposed permanent link mainly concerned the project's compatibility with existing international law, particularly where the bridge alternative is concerned. The evaluation conducted focused on the identification of elements of the future legal framework for the project that should be developed or explored further.

1. Evaluation of methodology

70. The studies compared the project with existing norms of international law in the affected sectors: navigation, the environment, international liability and transport. The methodological effort essentially involved the first of these areas, particularly the updating of appropriate legal instruments reconciling the sovereignty of the two States bordering the Strait with the right of passage of vessels of third States as a whole. During the period 1982-1992, the regime of the "right of innocent passage" evolved into the regime of "right of transit passage" established by the United Nations Convention of 1982 on the Law of the Sea.

2. Evaluation of results

71. The studies of international law have identified the following essential elements of the legal framework for the permanent link: (a) adoption of the "transit passage" regime for navigation in the waters of the Strait; (b) prior delimitation of Moroccan and Spanish territorial waters; (c) rules for separation of maritime traffic in order to guarantee the safety of navigation; (d) an environmental impact study, particularly for the bridge alternative; (e) definition of the responsibilities of the two promoting States, holders of concessions and users; and (f) border crossing regulations, harmonization of technical regulations for transport and coordinated planning of infrastructure. The evaluation confirmed the project's compatibility with international maritime law.

72. As for the construction and operation of the permanent link, the studies showed a preference for the public works concession alternative, as was the case for the English Channel link.

3. Conclusions and recommendations for future studies

73. The overall legal framework for the permanent link is far from complete. The principal elements of this framework have been identified. The programme of work for the current phase includes plans to pursue studies for this framework at the international and bilateral level, especially in the areas of maritime law and protection of the environment. The project's institutional aspects are also covered. The programme of work is therefore regarded as having an appropriate focus. As to future studies, although some could be continued, in most cases it would be wise to await the decision on the fundamental choice between the tunnel or bridge options before going any further. Moreover, the serious risks involved and the technical complexity of the project call for close cooperation between technicians and jurists in order to determine with care the impact of technical solutions on safety and the environment, for example, and to arrive at a precise assessment of liability.

IV. GENERAL CONCLUSIONS AND RECOMMENDATIONS

74. The studies conducted between 1982 and 1992 for the project for a permanent link through the Strait of Gibraltar, despite the diversity and complexity of the topics addressed, have led not only to substantial advances in the knowledge of essential aspects related to this major infrastructure project, but also, on the basis of methodologies considered acceptable for the most part, to interesting results which represent a reasonable and quite sound basis for the elaboration of a feasibility study for the project.

75. In particular, these studies have made it possible to state with a reasonable degree of certainty that no major geological obstacle exists to the construction of a permanent link through the Strait of Gibraltar and that the drilling of a tunnel is technically feasible within the limits of current tunnelling technology, despite the fact that it would be the deepest undersea tunnel in the world. The construction of the tunnel under the English Channel, although presumably less problematic, has certainly supported this position and

contributed useful experience. For a project of this magnitude, however, the knowledge of the geological characteristics of the submerged areas is considered insufficient.

76. Studies have also shown that the construction of a bridge, although under very demanding conditions, would also be technically feasible with existing technology. Up to the present, studies favour the "Bridge 28" (Ras Malabata-Punta Paloma) option, while the evaluation showed unexplored potential in the "Bridge 14" (Ras Cires-Punta Canales) option. Adaptations, refinements and extrapolations are still needed at this stage.

77. Even though the economic studies are naturally still preliminary and the anticipated traffic volumes are modest, the studies have also shown that the permanent link project has a reasonable economic basis. Its economic return will certainly not be very high, but it will be acceptable; with a subsidy amounting to about one third of the investment, the project would have a rate of return in the order of 9.5 per cent. One especially interesting result is that a major portion, about 40 per cent, of the welfare gain for users would take place in countries other than Spain or Morocco. This justifies the need for a multilateral project, including contributions by these countries to the partial subsidy needed for the investment.

78. As to future studies, the sectoral evaluations have led to the formulation of specific recommendations, the most important of which have been reproduced in the corresponding sections of this report. Because of its importance, knowledge of the geological characteristics of the submerged portion of the Strait remains the essential objective. From the viewpoint of the tunnel alternative, the best way of obtaining the necessary information would be by means of a reconnaissance gallery of a small diameter along the full length of the chosen route of the tunnel. In the absence of such a gallery, boring of the seabed must be continued once the geotechnical experiments planned for the current phase have provided experience with regard to the best methods of tunnelling through different ground types.

79. From the viewpoint of the bridge alternative, continued development of the crucial structural systems is recommended (adaptation of the technology of offshore platforms to the construction of piers, reinforcement and protection of piers against ship collision, aerodynamic stability of the superstructure up to 5,000 m in span range, and suspension system), as well as consideration of the introduction of a rail line in addition to the 2 x 2 lanes for road traffic. These studies should be carried out for the two proposed routes. For the Ras Cires-Punta Canales bridge, it will be essential to know the nature of the rocks at the point where the sea depth is 450 m, where the central pier will be constructed. It would also be desirable to study the forseeable impact of the construction of the piers on the undersea environment for both bridge alternatives.

80. In future economic studies, a better evaluation of the impact of the permanent link on local development is recommended, along with research on ways to improve it. A financial, economic and social evaluation of each of the present alternatives would also be appropriate.

81. In addition to the foregoing recommendations, it would also be useful (a) to evaluate the technical, economic and financial feasibility of the partial startup of the project, (b) to study structures already built or under construction in the region or elsewhere, in similar terrain, and (c) to evaluate the impact of the construction of bridge piers on the undersea environment.

82. The foregoing recommendations call, among other things, for parallel studies on three different options: one tunnel option and two bridge options. This appears most prudent given the current state of knowledge. As they are carried out, however, these studies should provide the essential elements that will serve as a basis, when the time comes, for the decision on the option to be selected, and will allow studies to be focused on that choice.

ANNEX

List of Studies

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